Sun-to-Ice: Do Solar Energetic Particle Events Cause Nitrate Deposition in Ice Cores?

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Nitrates in Ice Cores?

• In the past few decades, several authors have suggested that impulsive nitrate events observed in polar ice are associated with large solar proton events, e.g.,

• Zeller et al., 1986
• Dreschhoff and Zeller, 1990
• Dreschhoff et al., 1993
• Shea et al., 1993
• Zeller and Dreschhoff, 1995
• Dreschhoff and Zeller, 1990
• McCracken et al., 2001

• Recently, high-time-resolution ice core analysis [Kepko et al., 2009] has yielded some intriguing results

c.f., Traversi et al., HEPPA Workshop, 2011

Kepko et al., 2009

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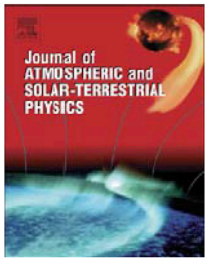

Interhemispheric observations of impulsive nitrate enhancements associated with the four large ground-level solar cosmic ray events (1940–1950)

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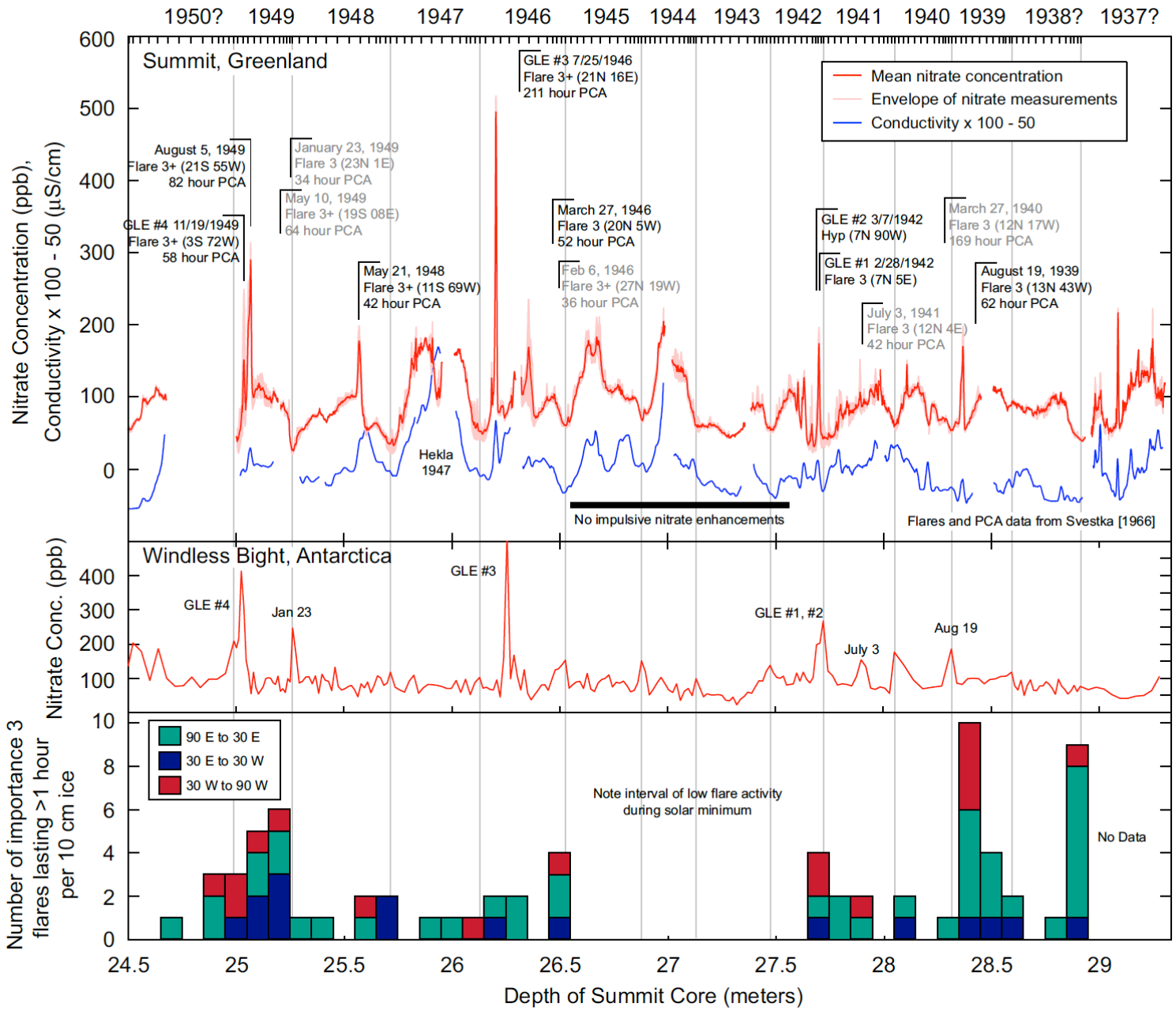
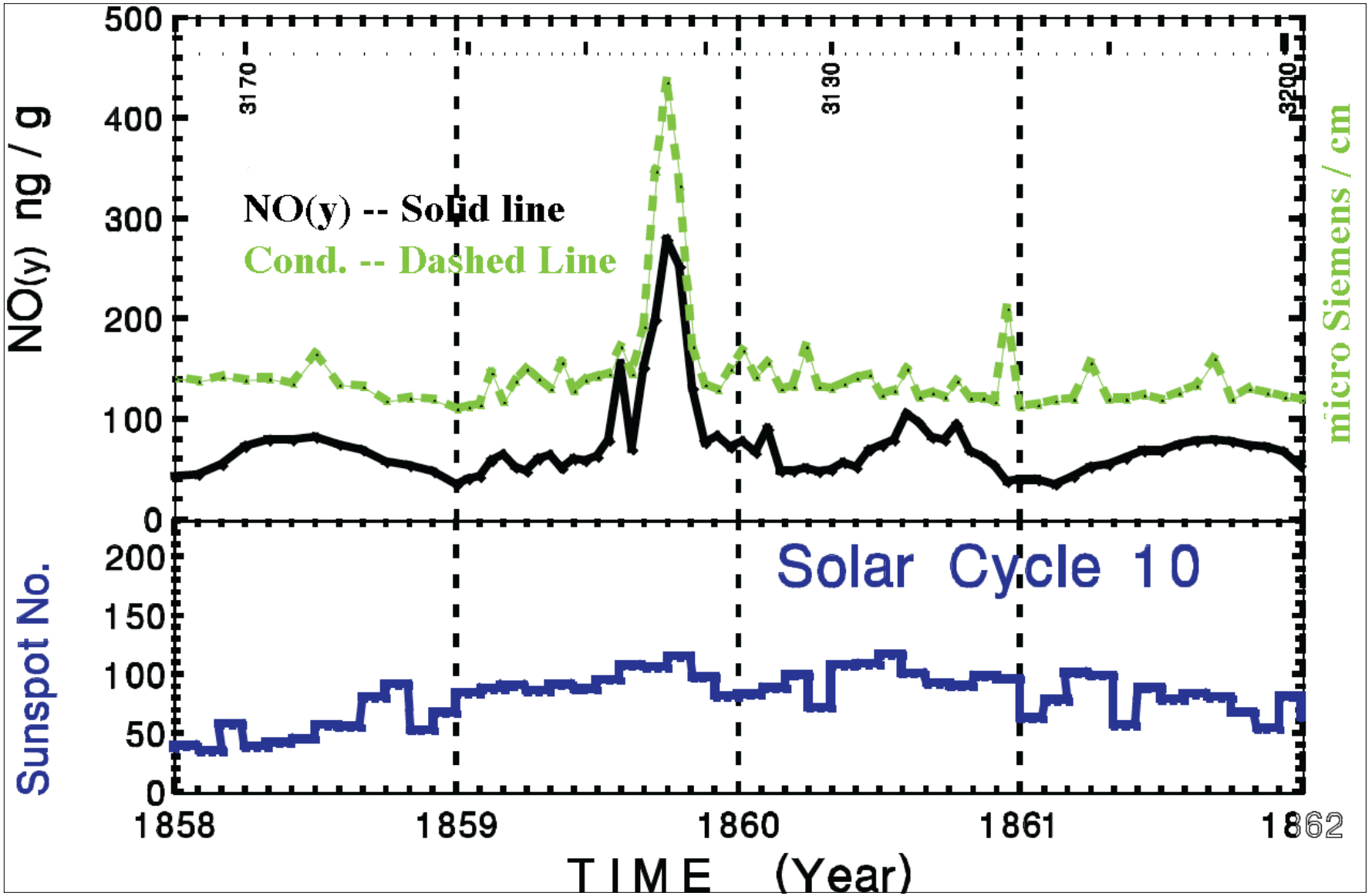
ABSTRACT

We present a compelling similarity of impulsive nitrate enhancements observed in polar ice from the northern and southern hemispheres. This analysis concentrates on the period 1940–1950, during which time the first four recorded solar cosmic ray ground-level enhancements (GLEs) occurred. GLEs are strong solar proton events. We show that large and sudden enhancements in the nitrate records from both hemispheres were observed within weeks following the recorded solar cosmic ray ground-level event. The observation of impulsive nitrate enhancements simultaneously in both hemispheres shortly after a large fluence solar proton event is strong evidence in support of a causal connection and argues strongly for rapid transport of atmospheric nitrates generated through the polar atmosphere by energetic solar proton events.

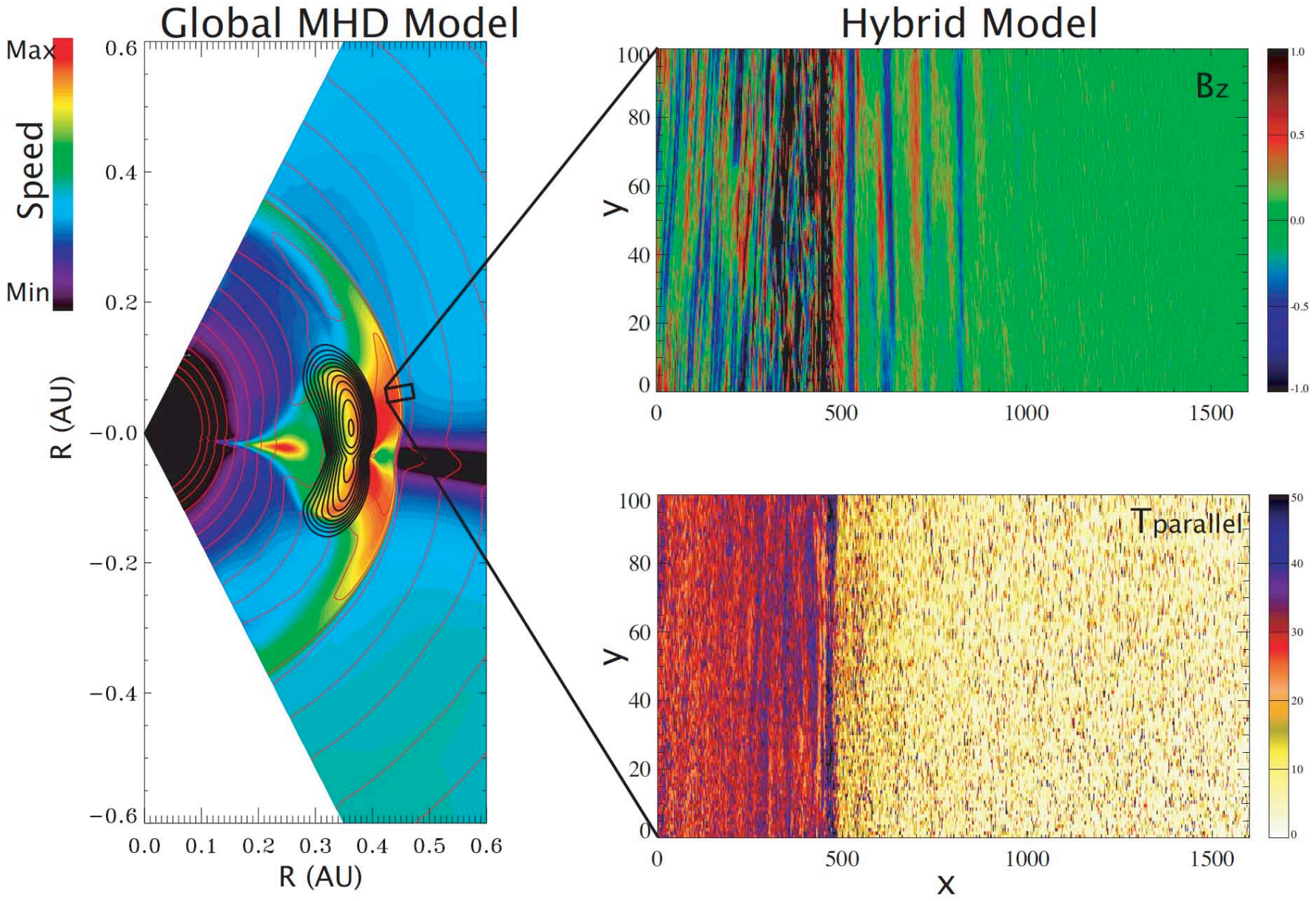
Nitrate Spikes Associated with Ground-Level Events



Nitrate Spike Associated with the Carrington Event

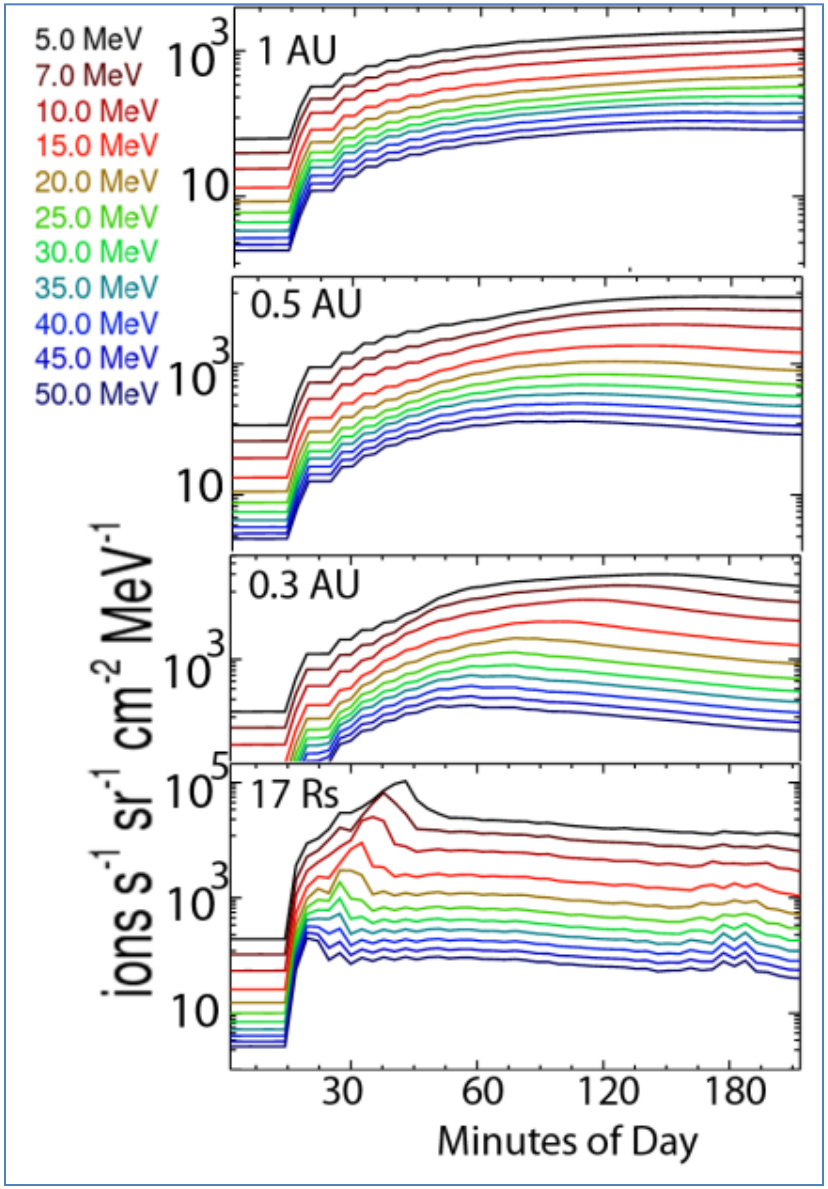


Solar Modeling — Acceleration of Energetic Particles



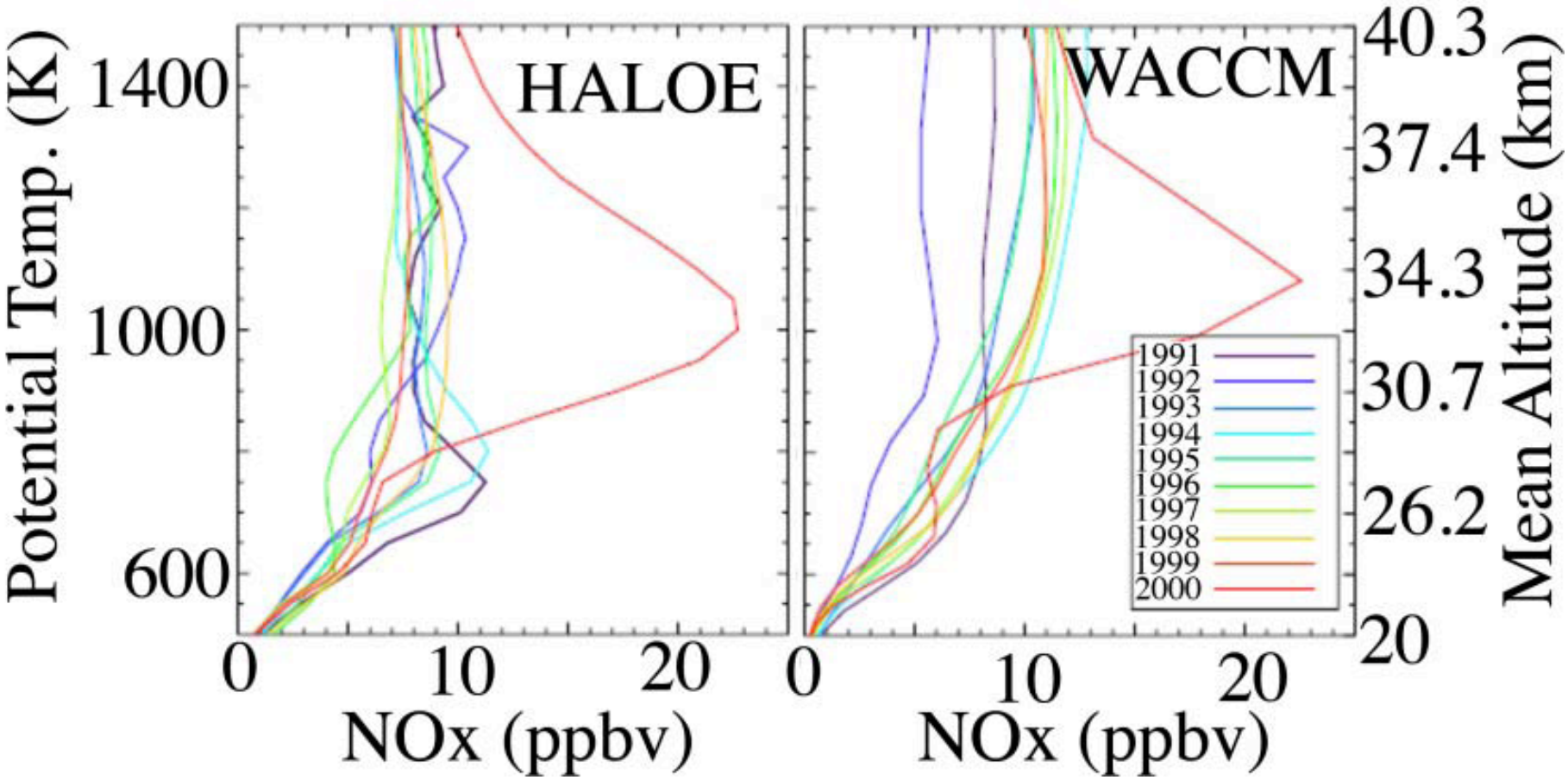
Work by Pete Riley and colleagues at Predictive Science, Inc. (PSI)

Heliospheric Modeling — Acceleration of Energetic Particles



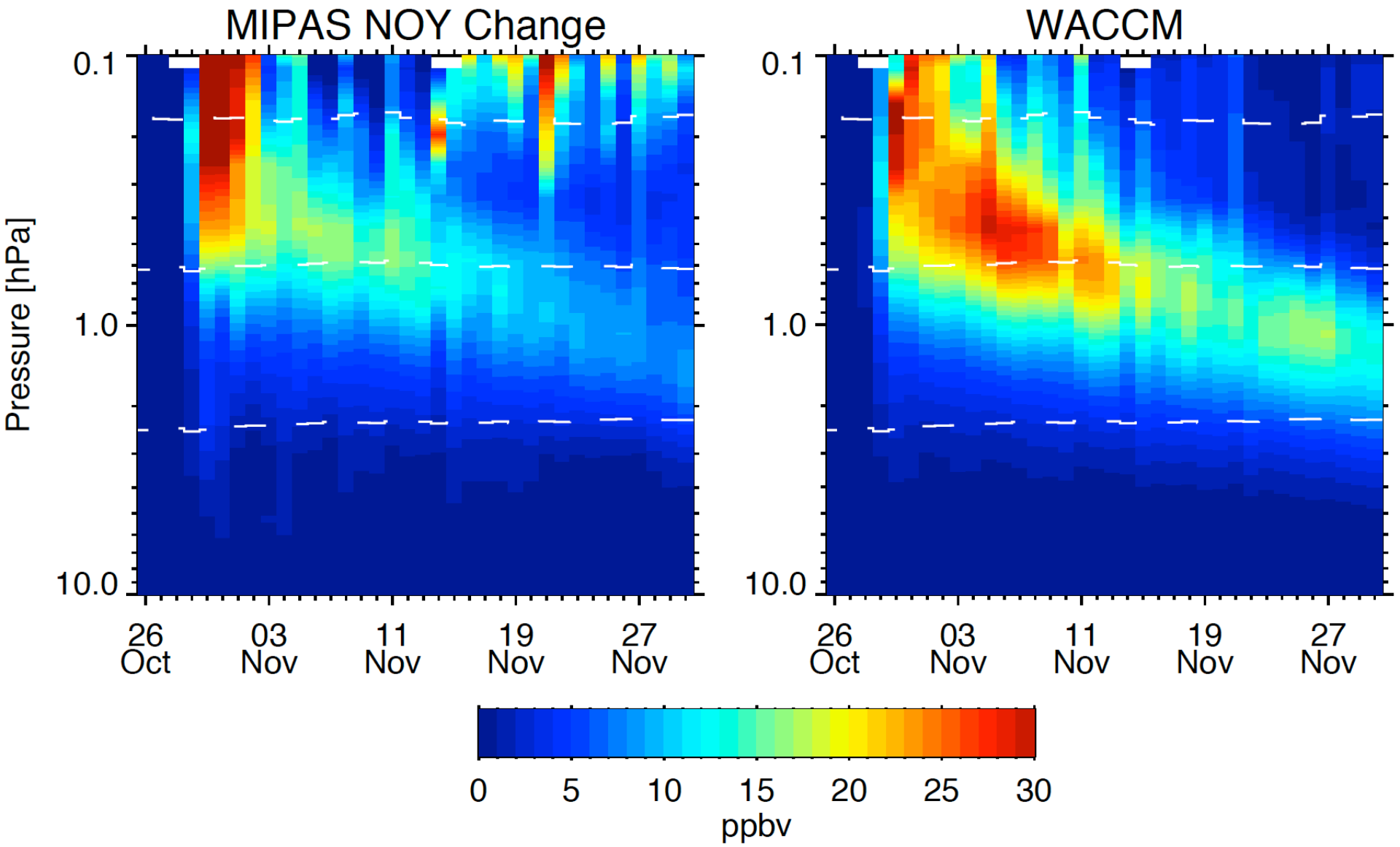
Calculations from the Earth-Moon-Mars Radiation Environment Module (EMMREM) [*Kozarev et al., 2011*]

Can SEPs Penetrate into the Atmosphere Deep Enough to Cause Ground-Level Nitrate Deposition?



Courtesy of Dan Marsh, Cora Randall, et al.

How Rapid and Effective are Transport Processes?



[*Funke et al., Atmos. Chem. Phys., 2010*]

Even if Nitrates can Reach the Surface, can they Survive Long Enough to End up in Ice Cores?

- Some skepticism among geochemistry experts that nitrates can survive long enough on ice surfaces to be buried.

- Speculation: it might work best in the absence of sunlight

- At any rate, they appear to be present in the core analysis products.

An Investigative Path

- The “Sun-to-Ice” project

- Funded by the NSF Frontiers in Earth Systems Dynamics

- Led by Harlan Spence at the University of New Hampshire

- Goal is to bring together scientists in solar corona, solar energetic particle, magnetospheric, particle transport, atmospheric dynamics, atmospheric chemistry, geochemical, and ice core, to study this problem

- Modeling and analysis of energetic particle generation and transport in the heliosphere and magnetosphere

- Comprehensive simulations of particle deposition, ionization, and chemical transport in the atmosphere

- A goal is to be able to use ice cores to say something quantitative about the frequency and magnitude of extreme solar events

- Many commonalities with the HEPPA community and other projects supported by the WACCM development team